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COMMUNICATION FACILITY EMP ASSESSMENT [redacted]

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

30 March 1979

Sanitized

Topical Report for Period 1 September 1975 — 30 March 1979

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Prepared for

Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

[redacted] This facility report presents the element descriptions, functional analyses element response assessments to the scenario variant nuclear EMP environment, and hardening concept designs for the equipment predicted to be damaged at [redacted] The assessments and hardening concepts are based on the most severe, high-altitude, nuclear EMP environment.

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[redacted] TABLE OF CONTENTS

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[redacted] SUMMARY [redacted]

[redacted] A scenario variant EMP assessment has been performed for the [redacted] Technical Control Facility and Microwave Terminal elements located at [redacted] The EMP assessment considered the effects induced by EMP environments generated by high-altitude nuclear detonations. The EMP assessment identifies the critical electrical/electronic equipment predicted to be impaired by the largest signals induced within the facility by any high-altitude nuclear EMP environment.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted] LIST OF ILLUSTRATIONS

[redacted]

[redacted]LIST OF TABLES

[redacted]

1.0 [redacted] INTRODUCTION

1.1 BACKGROUND

The Commander-in-Chief [redacted] and the Defense Nuclear Agency (DNA) have undertaken an Assessment of [redacted] Communications for Hardening to Electromagnetic Pulse [redacted] to assess the vulnerability of the [redacted] Command's [redacted] Command, Control, Communications and Computer (C^4) Networks to electromagnetic pulses from high altitude nuclear bursts and to provide recommendations for hardening as may be required. [redacted] Networks are used to link [redacted] with the National Command Authority (NCA), subordinate and component headquarters, and the [redacted] forces.

The Boeing Aerospace Company has developed and validated analytical techniques to predict the functional responses of a communications facility to the electromagnetic pulse (EMP) environment produced by a high-altitude nuclear weapon detonation scenario. The analytical capability has been applied to selected elements of the [redacted] C^4 Networks to develop response predictions in terms of upset and damage of facility equipment and functional impairments of facility communications capabilities.

This report concerns the Technical Control Facility (TCF) and Microwave Terminal (MWT) located at [redacted]

The TCF provides signal conditioning and routing functions for the [redacted] subscribers. The MWT serves as a prime communication link in the [redacted] network.

An on-site survey was conducted in August 1976 to determine the EMP features and element descriptions for use in the facility analysis. Equipment configuration and operational data were used to perform the electromagnetic

[redacted]

coupling and functional analyses of specified critical equipment. Computer models were developed to calculate the waveforms induced by EMP at significant terminals on critical equipment. The peak amplitudes of the waveforms were compared to calculated equipment damage and upset thresholds to predict the probability of the equipment surviving the most severe, high-altitude, nuclear EMP environment.

1.2 SCOPE

This report presents the element descriptions, functional analyses, element response assessments to the most severe, high-altitude, nuclear EMP environment, and hardening concept design packages for the critical equipment predicted to be vulnerable to the EMP environment at the [redacted] facility.

The hardening concept designs have been developed for each piece of critical equipment predicted to be vulnerable to the most severe nuclear EMP environment. The hardening concept designs are expected to reduce or nullify the EMP equipment effects, thus assuring critical equipment survivability to at least the 80 percent confidence level. The hardening concept designs consider the ease of installing and maintaining the hardening devices, cost, and non-interference to normal, daily operations.

Pages 7 through 12 were deleted

[redacted]

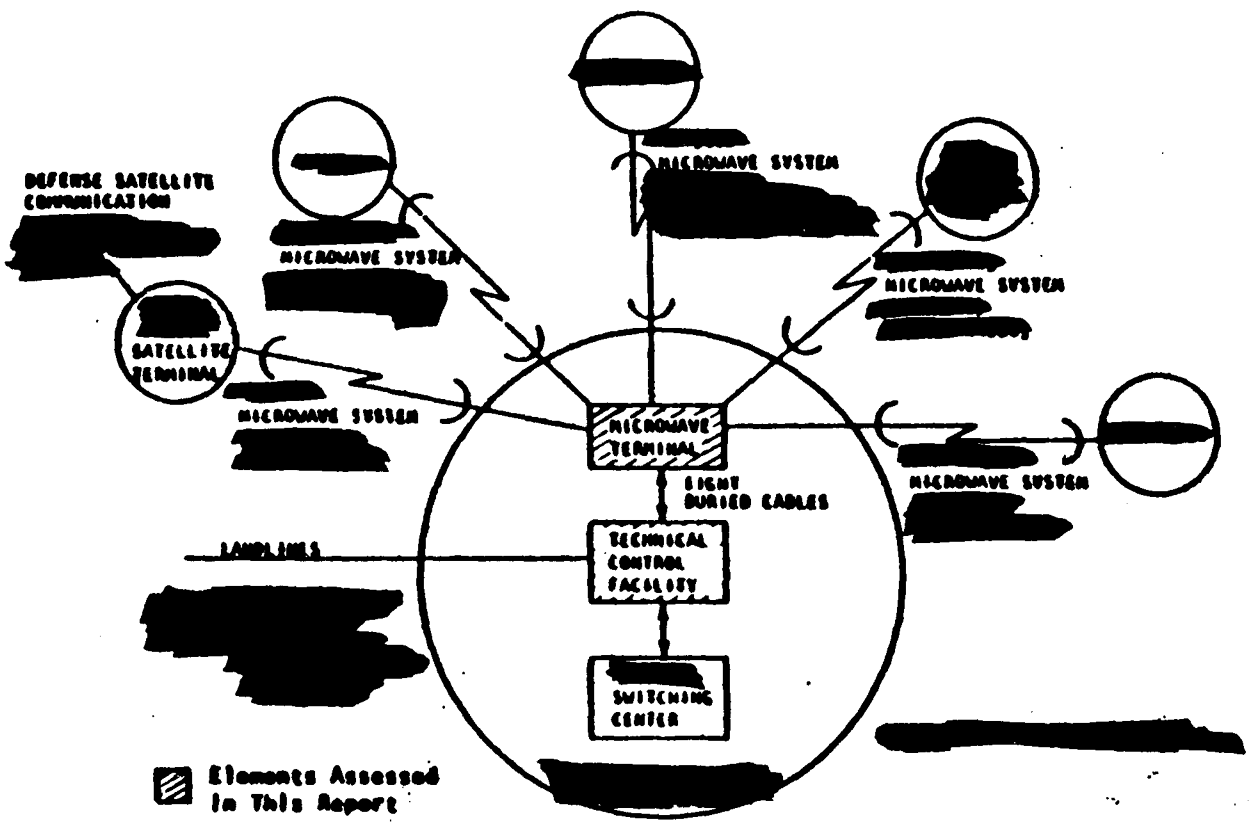

Figure 2.2-4. [redacted] connectivity.

[redacted]

[redacted]

3.0 [redacted] FACILITY HARDENING [redacted]

[redacted]

[redacted] Each of the two assessed elements in the [redacted] facility are addressed in this section and hardening concept designs are provided for each critical equipment susceptible to the EMP threat. Tables 3.1-1 and 3.2-1 list those equipments recommended for electromagnetic hardening in the TCF and MWT, respectively. The tables define techniques for hardening the equipment and the anticipated hardening improvement which would be achieved by implementing the hardening technique.

[redacted] The remaining material in this section defines conceptual designs for the hardening techniques recommended for installation in the [redacted] facility. The information presented includes recommended design requirements, material specifications, and installation instructions for each hardening concept. The hardening requirements are such that the modifications can be readily installed by on-site personnel. Some inspections by on-site personnel will be required to determine the proper equipment to be ordered.

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[redacted]

[redacted]

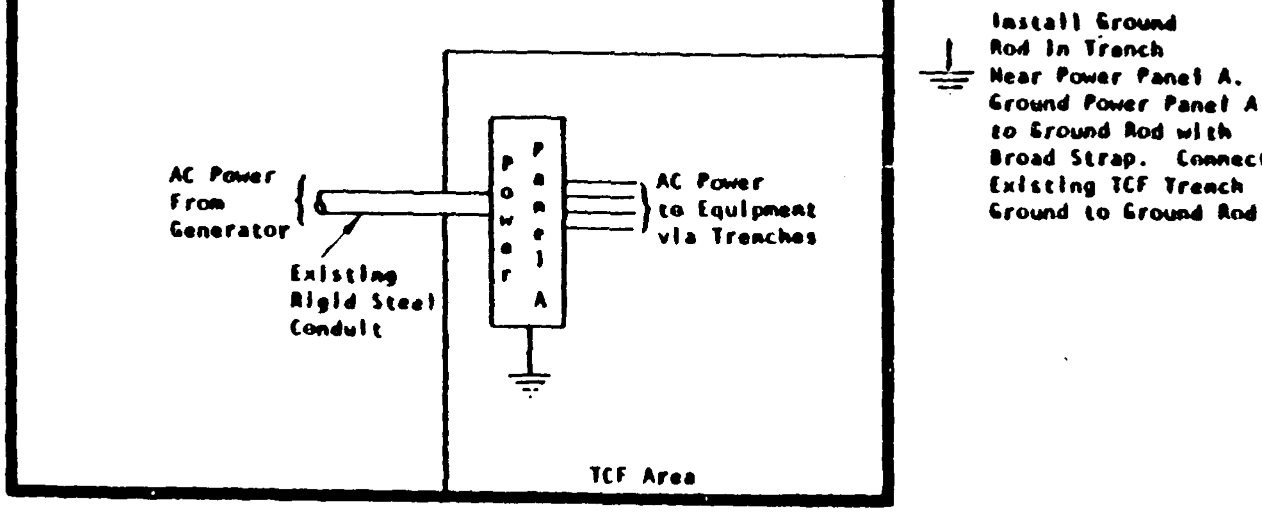

Figure 3.1-1. Conceptual installation of hardening techniques.

[redacted]

[redacted]

[redacted]

3.1.1 [redacted] AC Power Hardening Techniques [redacted]

3.1.1.1 [redacted] AC Power Panel Grounding. [redacted]

3.1.1.1.2 [redacted] Material Requirements. [redacted] An estimated list of material is shown in Table 3.1-2. The list also provides expected costs and potential suppliers.

3.1.1.1.3 [redacted] Installation Requirements. [redacted] Make a 2 inch diameter hole through the concrete in the bottom of the trench directly below power panel A. Drive the sections of the ground rod through the hole, using the couplings to tightly join each section, and the driving bolt and coupling to protect the threaded end of the rod during driving.

[redacted] Ensure that the neutral wires in power panel A are properly bonded to the panel metal box. Prepare metal surfaces per Appendix F to ensure proper bonding. Use existing box holes or drill new bonding holes to bolt the 2" x 1/8" copper strap to the metal box structure. Again prepare the mating surfaces per Appendix F. Route the copper strap down the TCF wall and into the trench, attaching the strap to wall as necessary. Form the copper strap to the ground rod and braze bond per Appendix F.

[redacted]

Table 3.1-2. AC power panel grounding, list of materials.

Item	Description	Supplier	Estimated Quantity		Approximate Cost/Unit	Total
			Per/Unit	Units		
1	Copper Weld® 3/4" x 6' Sectional Ground Rod Catalog #GRS346	1	3	1	$40.00	$40.00
2	Copper Weld® 3/4" Bronze Coupling for Sectional Ground Rods Catalog #GRC34	1	3	1	12.00	12.00
3	Copper Weld® Driving Bolt, 3/4" for Sectional Ground Rods Catalog #GRB34	1	1	1	2.00	2.00
4	Copper Strap 2" x 1/8" 8 Feet Long 3	2	---	8 Feet	16.00	16.00
5	AWG #4 Stranded Copper Wire 2 Feet Long 3	1	---	2 Feet	1.00	1.00
6	Miscellaneous Hardware 3	1	---	---	---	30.00
					Total:	$101.00

NOTES:

1. Obtain from nearest available source
2. Copper Weld Bimetallics Division Glassport, Pennsylvania 15045
3. Determine amount, size, type, etc. from installed equipment and hardening implementation requirements.

[redacted]

[redacted] Wrap an AWG #4 stranded copper wire around the ground rod and braze bond. Use a split bolt to compression bond the station ground wire in the trench to the AWG #4 stranded wire previously brazed to the ground rod. Make this ground wire as short as possible. Follow bonding instructions in Appendix F. Fasten station ground wire to trench floor one foot each side of ground rod to prevent breakage of compression or brazed bonds. Cut out a portion of the steel trench cover to allow the cover to be replaced without interference. See Figure 3.1-2 for the suggested ac power panel grounding installation.

[redacted]

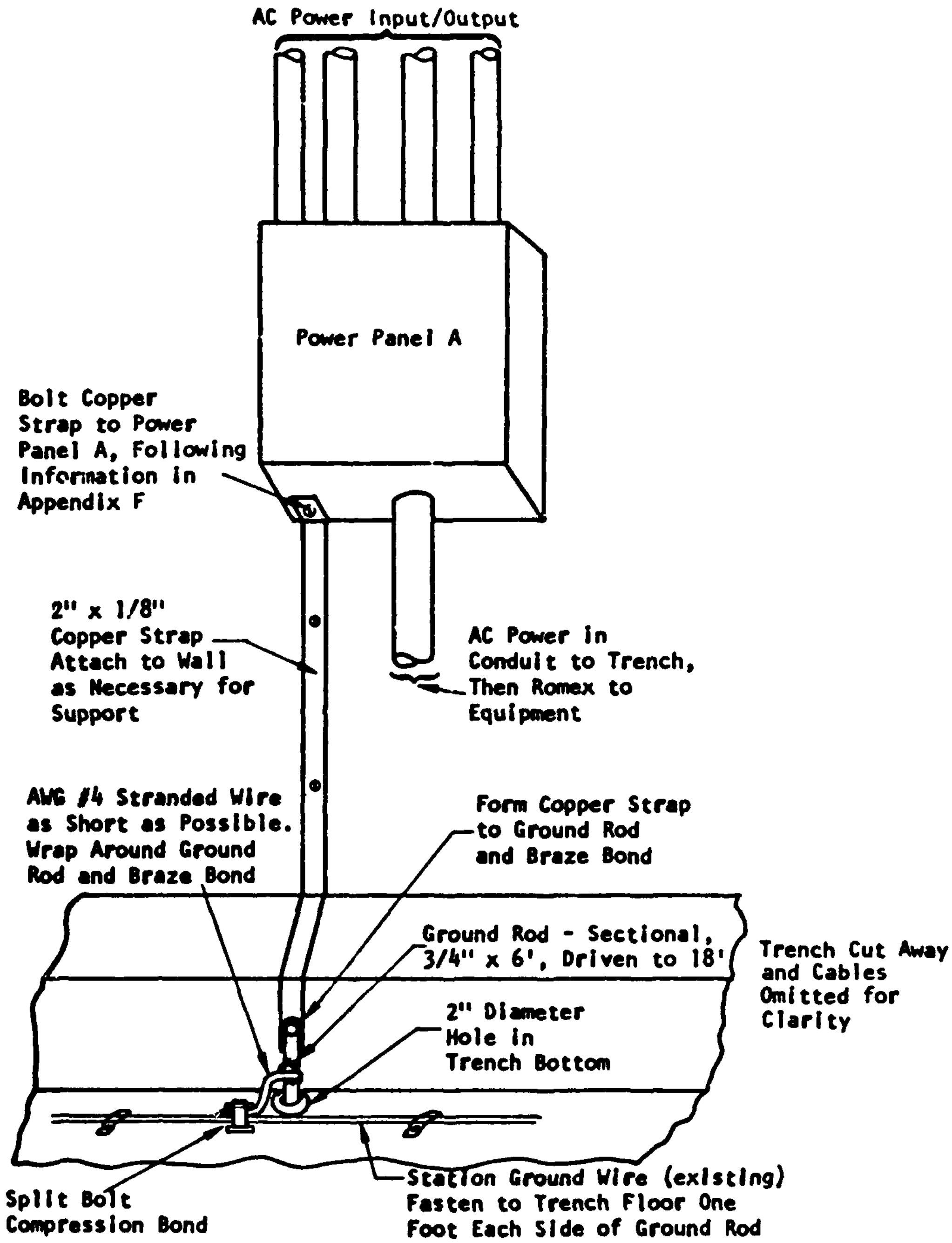

Figure 3.1-2. Suggested AC power panel grounding installation.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

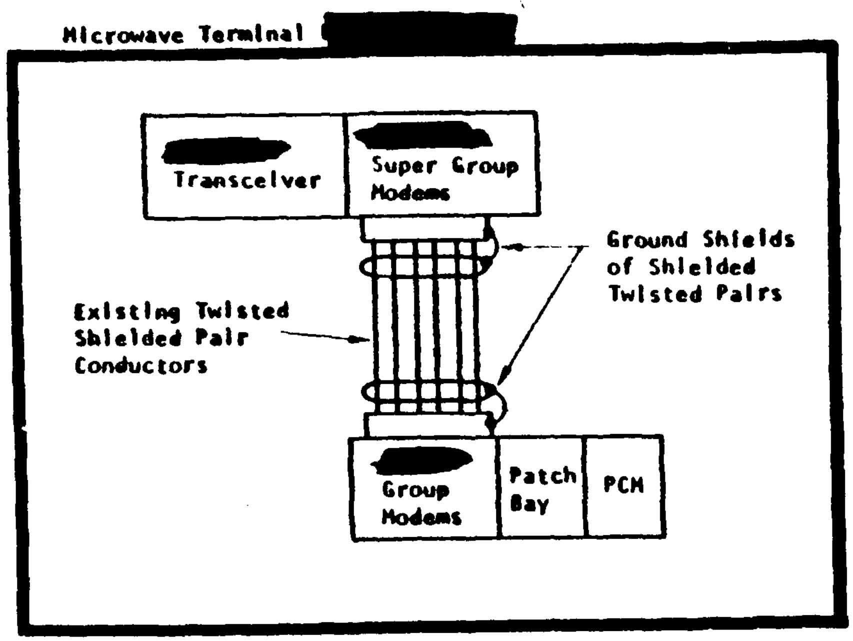

Figure 3.2-1. [redacted] installation of hardening techniques.

[redacted]

3.2.1 [redacted] Signal Input Hardening Concept Design [redacted]

3.2.1.1 [redacted] Signal Cable Shield Grounding. [redacted]

[redacted]

[redacted]

3.2.1.1.2 [redacted] Material Requirements. [redacted] An estimated list of materials is shown in Table 3.2-2. The list also provides expected costs and potential suppliers.

3.2.1.1.3 [redacted] Installation Requirements. [redacted] At the backplane connector of each of the six group modems and the two supergroup modems, install a shield grounding bracket fabricated from 0,030 copper sheet. This bracket mounts on the connector and is grounded to the equipment chassis using a 1 inch x 1/16 inch flat braid less than 4 inches long.

[redacted] At each connector, disconnect the twisted shielded pairs carrying the high frequency (group) signals from each terminal. Dress the end of each cable pair to expose 2 inches of shield and reterminate the connector pairs. Solder each cable shield to the grounding bracket as shown in Figure 3.2-2. Keep the shield pigtail as short as possible, approximately 1 inch. Connect the grounding strap to the bracket by soldering a 1 inch x 1/16 inch tinned flat copper braid to the bracket. At the other end of the braid attach a terminal lug by crimping

[redacted]

Table 3.2-2. Signal shield cable grounding, list of materials.

Item	Description	Supplier	Estimated Quantity		Approximate Cost/Unit	Total
			Per/Unit	Units		
1	Copper Sheet, 0.030" Thick by 6" Wide by 3 feet long ②	①	---	---	----	$30.00
2	1" x 1/16" Flat Tinned Copper Braid, 4 feet long ②	①	---	---	----	20.00
3	Miscellaneous Hardware ②	①	---	---	----	10.00
					Total	$60.00

NOTES:

① Obtain at nearest available source.

② Determine amount, size, type, etc. from installed equipment and hardening implementation requirements.

[redacted]

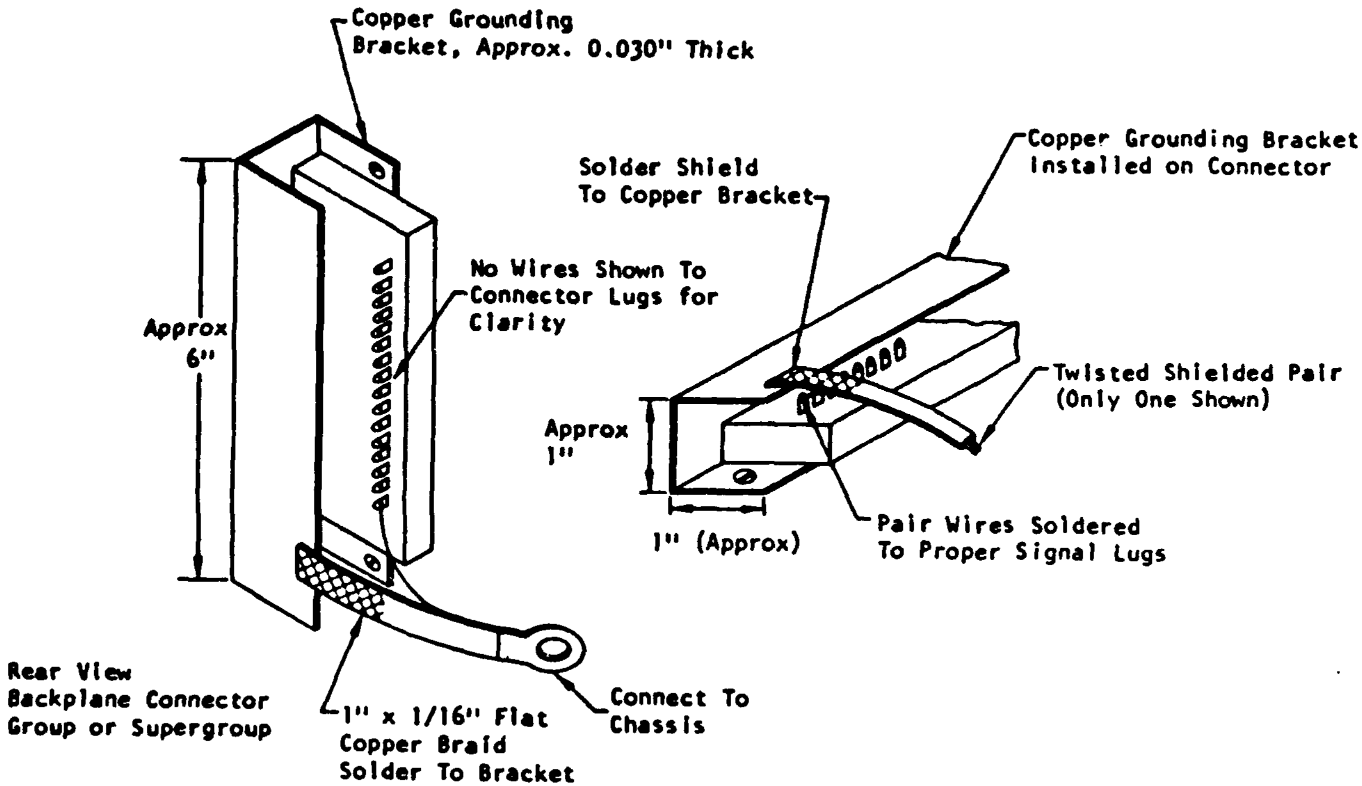

Figure 3.2-2: [redacted] Typical Backplane shield grounding of high frequency (group) signal pairs.

[redacted]

[redacted]

and then soldering. Keep the braid as short as possible (approximately 4 inches) allowing the connector to be removed. The chassis termination is to be made by using existing mounting holes or locating new holes to terminate the ground braid. Bond the grounding braid per the instructions in Appendix F.

[redacted]

[redacted]

APPENDIX A

[redacted] EMP ASSESSMENT PREDICTIONS [redacted]

A.1 [redacted] GENERAL

A scenario variant (SV) assessment technique was used for assessing the effects of EMP on the Technical Control Facility and Microwave Terminal at the communications facility at [redacted] Using the SV technique provides for making element assessments, and developing hardness concept design packages to provide a desired survival confidence level, for the most severe, high-altitude, nuclear burst EMP environment.

The EMP assessment predictions are calculated by using the scenario variant assessment technique described in Appendix B.

A.2 [redacted] SCENARIO VARIANT ASSESSMENT DATA [redacted]

[redacted] The scenario variant assessment predictions for the critical equipment items are provided in Tables A.2-1 and A.2-2. For each critical equipment item, the largest predicted peak voltage and associated pulse frequency are provided, as are the upset and damage thresholds. Tables A.2-1 and A.2-2 also provide the safety margin and survival confidence values for each critical equipment item. The safety margin and survival confidence predictions each depend upon the predicted peak voltage. Since the SV assessment technique defines the maximum potential EMP-induced peak voltage at the critical equipment interface, the predicted safety margin and survival confidence values are the minimum levels expected for any high-altitude nuclear EMP environment condition.

[redacted] The predicted safety margin is the ratio, in dB, between the threshold voltage and the predicted peak voltage. The survival confidence values were determined using the predicted safety margins and the data quality distribution which characterizes the statistical uncertainties in safety margin predictions. For the calculations used for this assessment, the data quality distribution was chosen as normally distributed with a zero mean and a standard deviation of 8 dB. This distribution was used since it is the data quality indicated from previous test experience.

[redacted]

[redacted]

[redacted]

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[redacted]

[redacted]

APPENDIX B

[redacted] EMP VULNERABILITY ASSESSMENT TECHNIQUE

B.1 GENERAL

The assessment technique is a step-by-step procedure to gather and process the necessary information to arrive at an element assessment. The technique consists of nine operations:

1) Perform a site survey
2) Develop a functional description of the equipments and the element
3) Define the equipment critical to element operations
4) Provide a floor plan showing all equipment locations
5) Produce an equipment list for inherently survivable equipment
6) Calculate threshold values for each critical equipment
7) Develop element-level computer models
8) Calculate critical equipment responses to scenario variant nuclear EMP environment
9) Propose hardening techniques and modifications for predicted vulnerable equipment

Each of these nine operations is amplified in greater detail in the following paragraphs.

B.1.1 Site Survey

The test team reviewed all on-site documentation relating to the physical configuration of building and local, surrounding structures.

Drawing of the facility area was made to show the relationship between the structure housing, the critical equipment and the external collectors of EMP energy. Typical external collectors plotted are

[redacted]

[redacted]

1) Power poles
2) Transformers and power switches
3) Ground or counterpoint systems
4) Antennas
5) Towers
6) Weatherheads and power drops
7) Communications cable routing
8) Incoming ac transmission links

The plot plans for the elements of the facility are in Appendix C.

B.1.2 Facility Functional Description

The on-site documentation also provided a functional description of the facility. The functional description was used to gain an understanding of the operating characteristics of the different systems in the facility and the equipments comprising the systems. The knowledge of how the systems and equipments work and interrelate with each other was used to evaluate the responses of the systems and equipments to the EMP environment. The responses have been translated into operational capabilities lost or remaining during and after an EMP event.

B.1.3 Critical Equipment Definition

The on-site documentation was reviewed to identify those equipments which support critical [redacted] C^4 Networks and the equipments so identified were reviewed by site personnel. A critical piece of equipment was defined as that equipment considered essential for operating a critical subsystem. A critical subsystem performs a primary function, and the loss of the function results in a reduced system capability.

[redacted]

[redacted]

B.1.4 Critical Equipment Layout

An equipment layout plan was developed showing the location and orientation of each piece of critical equipment within the building structures. Major internal coupling paths, such as cable trays, ducts and conduit, were included. Appendix B shows the critical equipment layouts for the elements considered in this report.

B.1.5 Survivable Equipment List

From the list of critical equipment, those equipments which prior assessment experience indicates has a safety margin of [redacted] or greater were eliminated from further analytical consideration. Such items were classified as hard and survivable at the [redacted] percent confidence level. The remaining critical equipment items received analysis emphasis.

B.1.6 Critical Equipment Thresholds

Damage thresholds were developed for the remaining items on the critical equipment list. The voltage or current thresholds beyond which equipment damage occurs were calculated using the equipment characteristics defined in the on-site documentation, and previously developed analysis and mathematical modeling techniques. The predicted thresholds were calculated on the basis that the specific equipment is expected to be damaged if the predicted threshold levels are attained or exceeded. The damage thresholds for the TCF and MWT critical equipment are listed in Appendix A.

B.1.7 Computer Models

Computer models were developed for the critical equipment, the facility functional systems, facility coupling paths and penetration points, and the external electromagnetic energy collectors using the site survey and equipment

[redacted]

documentation data. The models were used to represent the TCF and MWT elements; external environment computer software programs were used to calculate the response waveforms induced by the EMP environment at the critical equipment interfaces in each element.

B.1.8 Scenario Variant Assessment

The scenario variant (S/V) assessment technique uses a software program that defines seventeen nuclear bursts in the hemisphere above a ground facility and mathematically propagates the EMP from each burst against the models representing the critical equipment, functional systems, coupling paths, penetration points, and the external electromagnetic collectors for an element. [redacted]

The predicted damage responses calculated using the S/V technique for each critical equipment in the TCF and MWT elements are tabulated in Appendix A.

B.1.9 Hardening Techniques and Design Packages

Hardening techniques were developed for each critical equipment predicted to be vulnerable to the most severe, high-altitude nuclear EMP environment. Tables listing equipment requiring electromagnetic hardening, and recommended hardening techniques are in Section 3.0. Hardening design packages were developed for each vulnerable critical equipment from the hardening techniques, and are also contained in Section 3.0.

[redacted]

APPENDIX C

[redacted] FACILITY SITE DESCRIPTION

C.1 GENERAL

[redacted]

[redacted] house the Technical Control Facility (TCF) and Microwave Terminal (MWT), respectively. Each of these buildings is a single story structure, with a limited amount of steel reinforcement. Figure C.1-1 shows the locations of these buildings in a partial plot plan of [redacted] Figures C.1-2 and C.1-3 are pictorial views of the TCF and MWT, respectively.

C.2 PHYSICAL DESCRIPTION [redacted]

C.2.1 TCF Equipment Layout

The TCF equipment layout is shown in Figure C.2-1. The TCF contains equipment necessary to provide a means of properly connecting and conditioning incoming and outgoing signals.

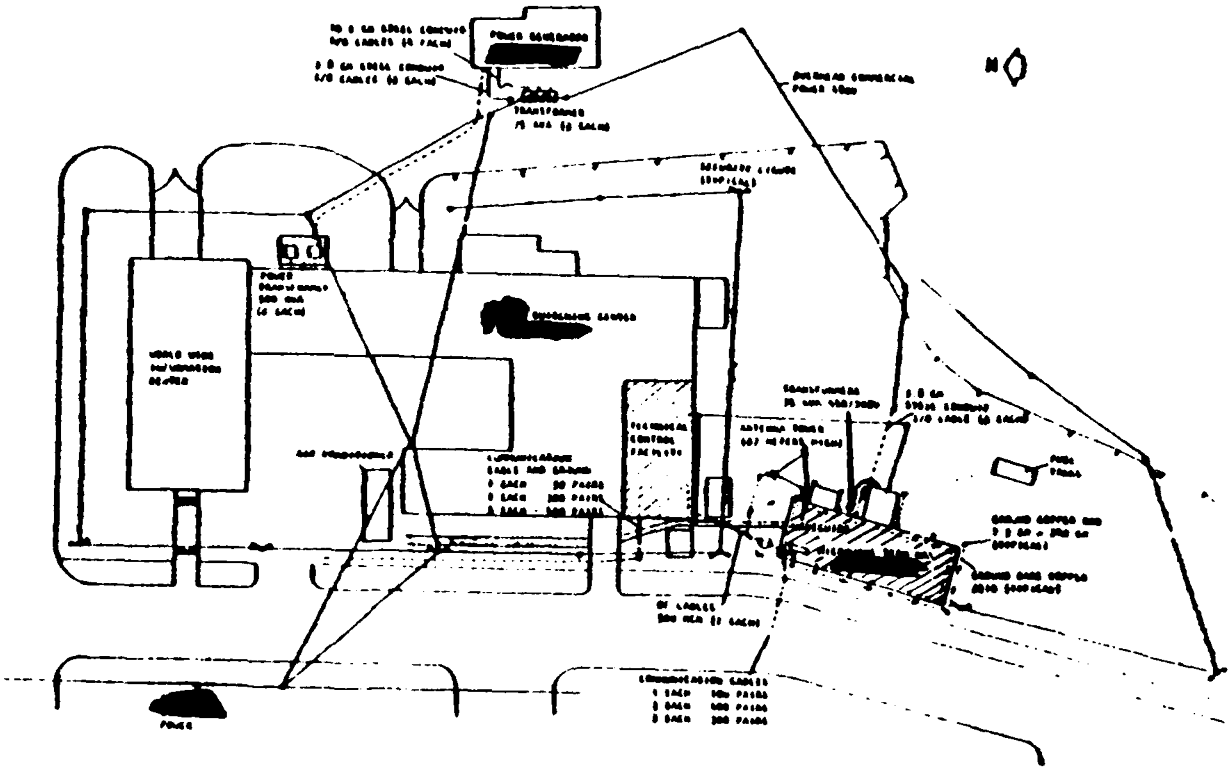
C.2.2 TCF Communication and Ground Cables

All communication cables penetrating [redacted] are buried. The communication cables penetrate the TCF at two locations as previously shown in Figure C.1-1. Signal cables within the TCF are routed on cable trays and in cable trenches. The signal cables are shielded and twisted pair cables. Cable shields are grounded to the signal ground bus at each equipment rack.

The facility grounds are divided into signal and power grounds. The signal ground bus is located in the distribution frame. All equipment signal grounds are tied to the ground bus in the distribution frame. This signal ground bus is connected to a ground junction bus located in the cable trench subsequently connected

[redacted]

[redacted]



Elements Assessed in This Report

Figure C.1-1. Locations of TCF and MWT on partial plot plan [redacted]

[redacted]

[redacted]

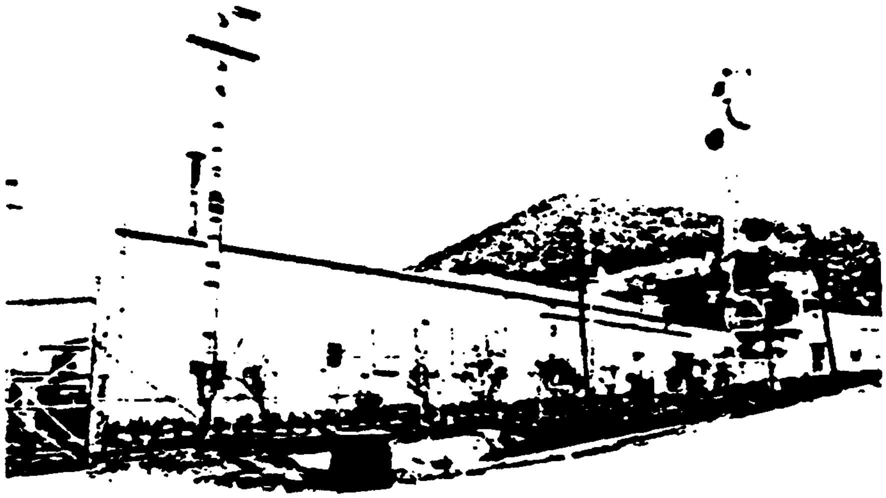


Figure C.1-2. Pictorial view of the TCF, [redacted]

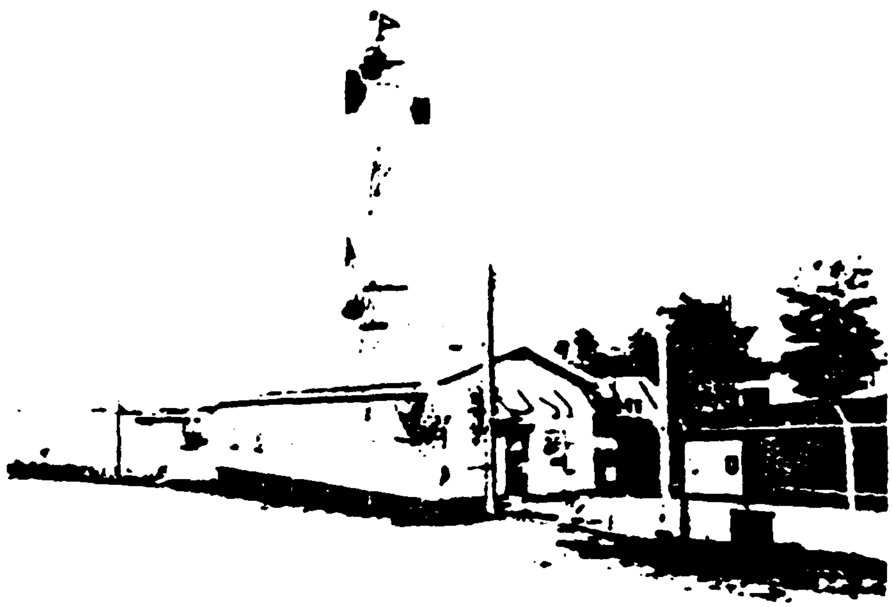


Figure C.1-3. Pictorial view of the HWT facility, [redacted]

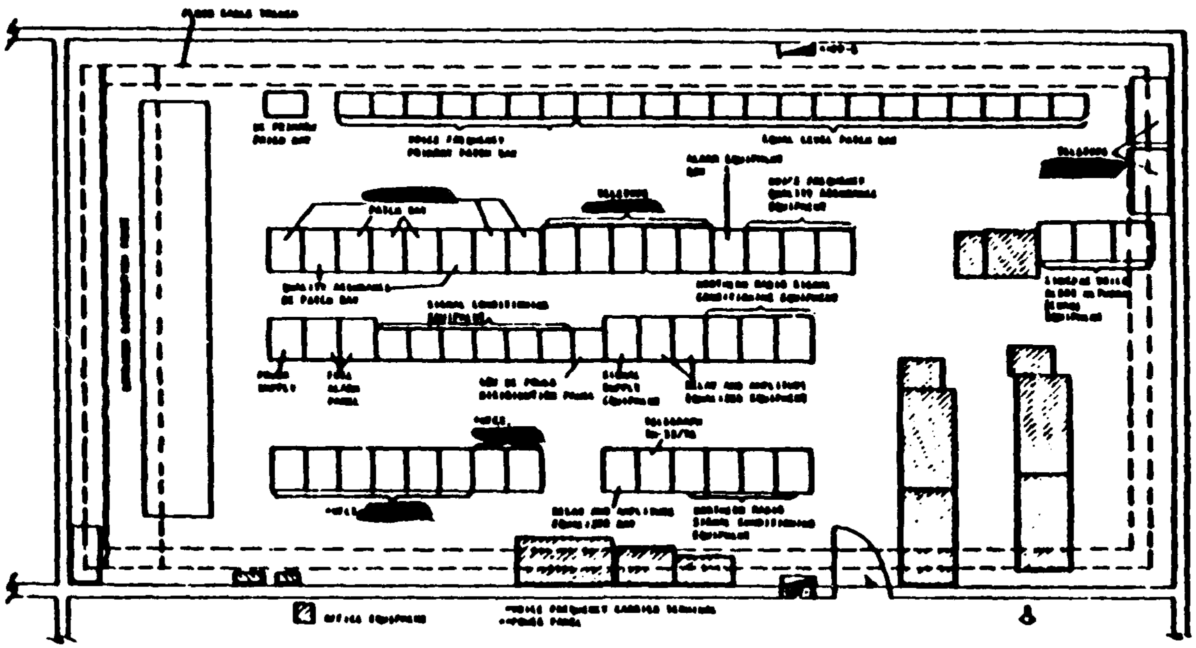


Figure C.2-1. [redacted] TCF equipment layout.

[redacted]

to the exterior ground network by a bare 4 AWG copper cable. All equipment frame grounds and dc power grounds are connected to this ground junction bus. AC power grounds are tied to the power ground network of the [redacted] Switching Center.

C.2.3 TCF AC/DC Power Subsystems

Commercial ac power is supplied to the site power plant [redacted] transformers by overhead transmission lines. These three 75 kVA transformers are mounted on a pole 9 meters (29.5 feet) above ground level. AC power is then routed by buried cables to the circuit breaker in [redacted] Emergency ac power is provided by four 500 kW diesel generators located in the site power plant.

AC power is supplied to the facility by two pad mounted transformers located outside the northeast corner of [redacted] Each transformer is rated at [redacted] AC power is routed to these transformers by two buried feeders from the site power plant, [redacted] The feeder cables (size 1/0 - 3 each) are routed in 3.8 centimeter buried conduits.

AC power within the building is distributed to the TCF equipment in steel conduits.

The [redacted] circuit conditioning equipment uses commercial 115 Vac power. Some of the [redacted] equipment converts the ac power to 48 Vdc.power. Most of the conditioning equipment for the other voice and data circuits use 115 Vac power.

DC power is supplied to the TCF by three 400 ampere dc rectifiers located in the microwave terminal, [redacted] The dc power is routed to the TCF by two buried 500 MCM (thousand circular mills) cables. DC power is also provided by individual equipment power supplies.

The [redacted] single frequency signaling units and line amplifiers are powered by 48 Vdc, as are the current regulators. The dc power is supplied from

[redacted]

[redacted]

the MWT building by redundant 48 Vdc battery banks constantly charged by three [redacted] rectifiers. The battery banks provide a minimum of four hours reserve for both the TCF and MWT in the event of ac power failure.

C.3 PHYSICAL DESCRIPTION [redacted]

C.3.1 MWT Equipment Layout

The MWT equipment layout is shown in Figure C.3-1. The [redacted] microwave system is used to communicate with the [redacted] facility. A [redacted] microwave system is provided to communicate with the [redacted] facility. The [redacted] radios are used to link [redacted] with [redacted] and the [redacted]. The microwave terminal uses the [redacted] and [redacted] multiplex systems for the [redacted] and [redacted] and [redacted] and [redacted] respectively.

C.3.2 MWT Communications and Grounding Cables

Communication cables originate in the technical control area [redacted] carrying telephone and message traffic to and from the MWT. Signal cables are routed within the MWT on cable racks 2.4 meters above the floor. These cables consist of shielded and unshielded twisted pairs. The individual cable shields are grounded to the signal ground bus at each equipment rack.

The MWT facility's signal and power ground buses are tied to an interior grounding network. This network consists of bare 1/0 copper wire running on the overhead cable racks. This cable is connected to the exterior ground counterpoise system by 1/0 copper cables at various points around the building. Equipment racks and dc returns are also grounded to the interior ground network.

[redacted]

[redacted]

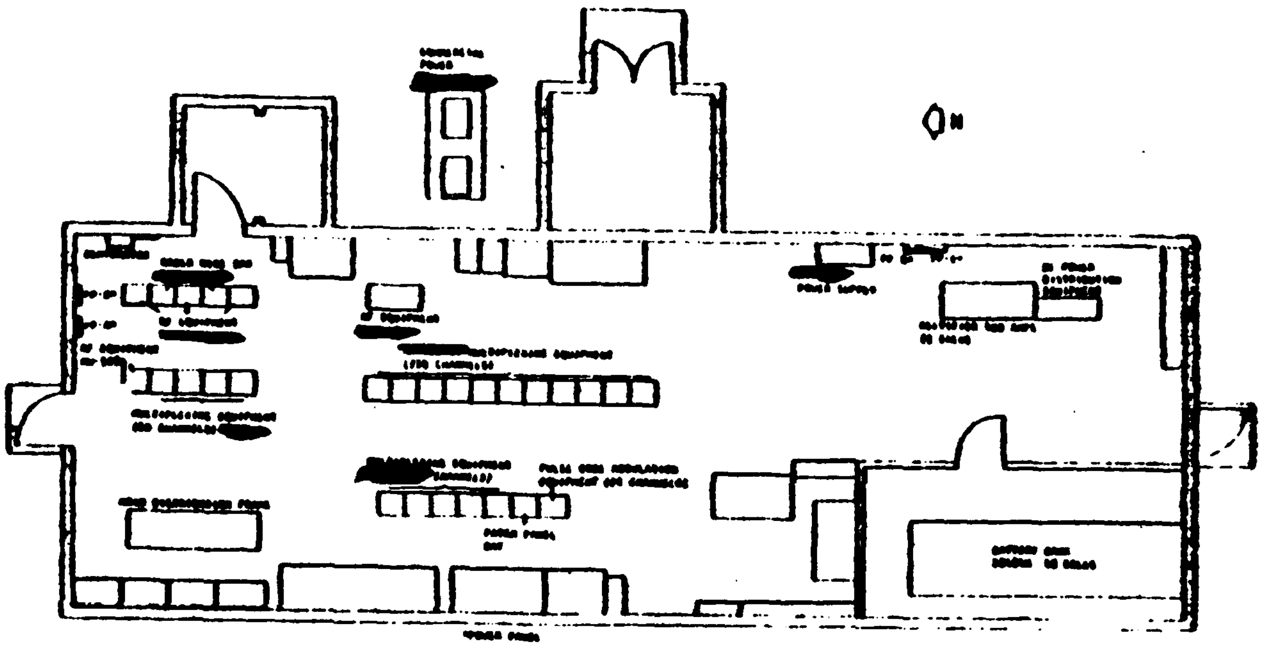


Figure C.3-1. [redacted] equipment floor layout.

[redacted]

C.3.3 MWT AC/DC Power Subsystems

The site power plant i[redacted]receives commercial ac power by overhead transmission lines to three power plant transformers rated at 75 kV. The transformers are mounted on poles 9 meters (29.5 feet) above ground. AC power is then routed from these transformers by buried and overhead cables to the two transformers by the MWT (see Figure C.1-1). Emergency ac power is provided by four 500-kW diesel generators located[redacted]

AC power is supplied to the facility by two pad-mounted transformers located northeast of[redacted] Each transformer (480V/208V) is rated at 75 kVA. AC power is distributed in steel conduits to the individual MWT equipment.

DC power is supplied to the MWT equipment by three 400 ampere dc rectifiers and by individual equipment power supplies. The power supplies also charge two 24-cell, 48 V battery banks located within the building to provide a minimum 8-hour emergency power reserve.

C.3.4 MWT Grounding System

The facilities exterior ground counterpoise system surrounds [redacted]as shown in Figure C.1-1. The exterior ground network consists of buried 1.9 centimeter x 240 centimeter long copper rods connected together by bare 2/0 copper cables. The interior ground cable, five waveguides, antenna tower, air conditioning units and transformer cases are externally grounded to this ground counterpoise system.

[redacted]

APPENDIX D

[redacted] FACILITY FUNCTIONAL ANALYSIS

D.1 GENERAL

The TCF at [redacted] is operated and maintained by the [redacted] The primary function of the TCF is to provide the [redacted] communication facility access to long haul communication networks. The TCF provides the communication facility with the necessary connecting and signal conditioning equipment for all message traffic.

The primary function of the microwave terminal is to provide continuous multiple channel transmission between the [redacted] communication facility and five interconnecting [redacted] facilities.

The connectivity [redacted] is shown in Figure D.1-1.

D.2 ELEMENT FUNCTIONAL DESCRIPTIONS

D.2.1 Technical Control Facility (TCF)

The TCF provides signal conditioning and routing functions between [redacted] subscribers. Message traffic entering and leaving the TCF is single channel voice frequency over twisted pairs and low-level [redacted] over twisted pairs. Figure D.2-1 shows the communications signal flow and associated equipment.

Results of the functional analysis indicate that the equipment listed in Table D.2-1 are critical for operating the [redacted] TCF. Included for each critical equipment is the functional impact to TCF operations if the equipment is impaired.

[redacted]

[redacted]

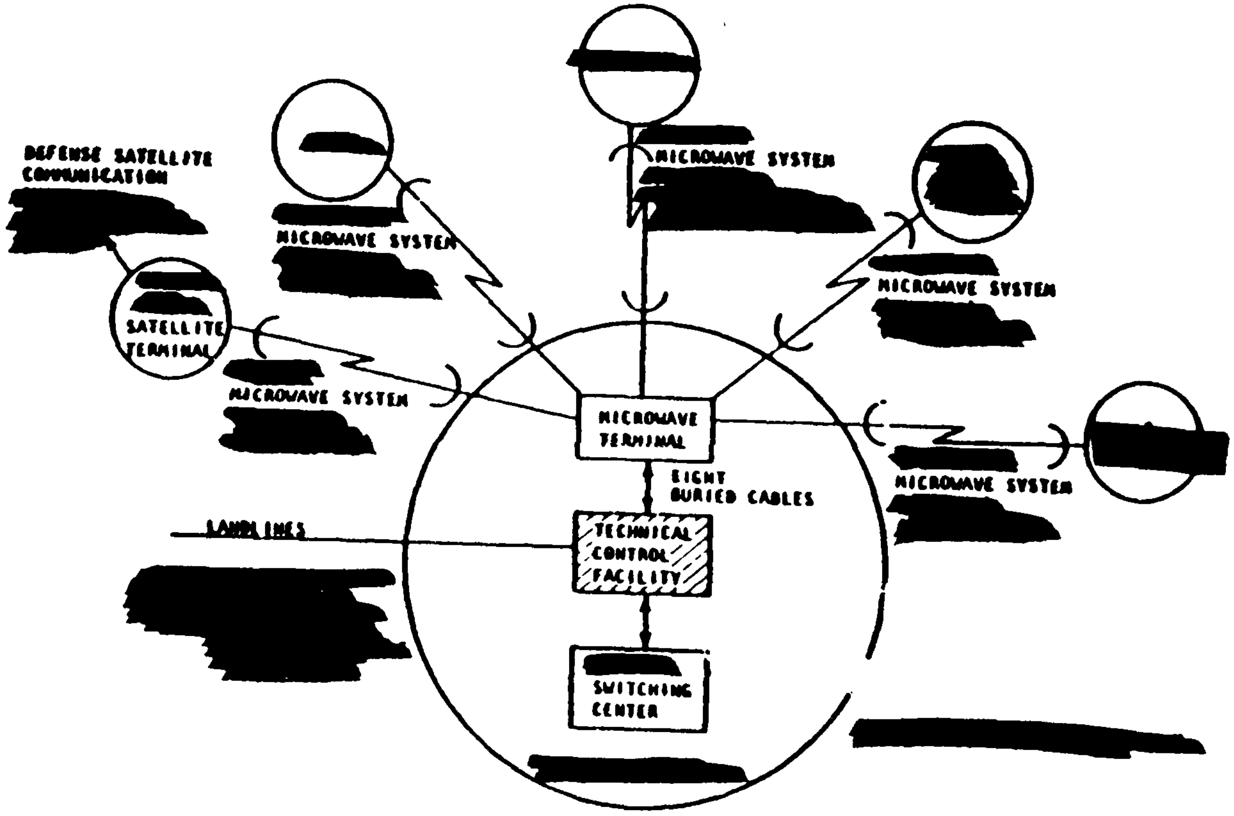


Figure B.1-1. [redacted] connectivity.

[redacted]

[redacted]

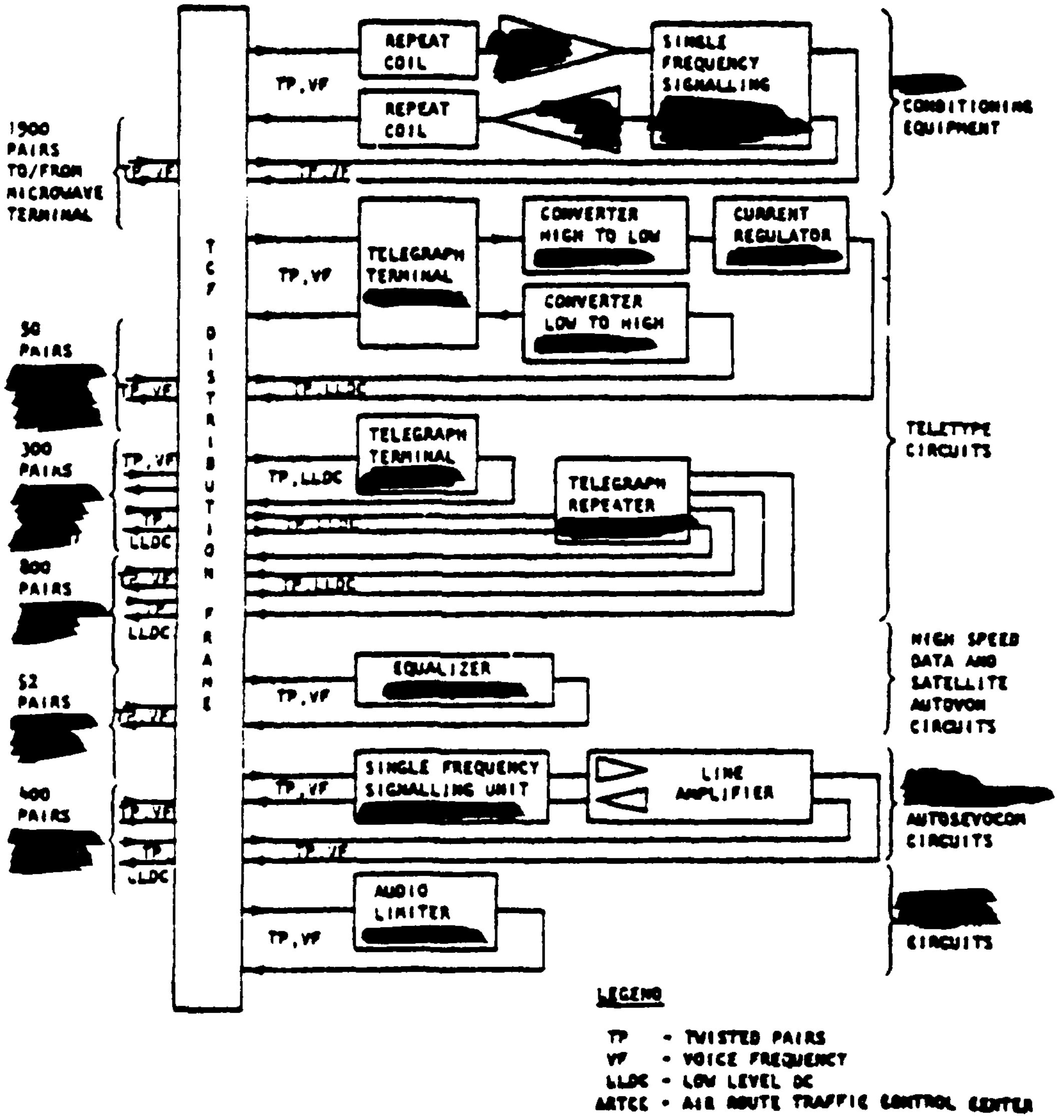


Figure D.2-1. Communications signal flow and associated equipment.

[redacted]

[redacted]

[redacted]

Table B.2-1. TCF functional response matrix for critical equipment.

Critical Equipment	Functional Response
Power Supply [redacted]	Failure results in the loss of the [redacted] circuits. Restoral is by repair, or by patching to the station [redacted] Vdc battery (1 hour operation).
Single Frequency Signaling Unit [redacted] Line Amplifier, [redacted]	Failure results in the loss of the [redacted] circuits. Some spares are available for restoring the unit, or a patch can be implemented to [redacted] dedicated units in the TCF (1 hour operation).
Repeat Coils	Failure results in the loss of the [redacted] circuits. Some spares are available for repairing the coils.
Telegraph Terminal, [redacted]	Failure results in the loss of [redacted] circuit modulation/demodulation. Some spares are available for repairing the unit.
Equalizer, Amplitude + Delay [redacted]	Failure results in the loss of the [redacted] satellite circuits, the 2400 baud and higher [redacted] and [redacted] circuits, and the [redacted] circuit [redacted]. Restoral is by replacing with some spares, repair, or by patching around the equalizer. However, patching will badly degrade signal quality.
Single Frequency Signaling Unit [redacted]	Failure results in the loss of [redacted] and [redacted] circuits, and circuits through [redacted]. Some spares are available for repairing the unit.
Line Amplifier [redacted]	Failure results in the loss of some high data rate circuits from [redacted] and/or [redacted] to end user near [redacted]. Restoral is by replacing the units (some spares are available), or by patching around the amplifiers, if the loss in signal quality is acceptable.
Line Amplifier [redacted]	

[redacted]

Table B.2-1. TCF functional response matrix for critical equipment (continued).

Critical Equipment	Functional Response
Telegraph Terminal, [redacted]	Failure results in the loss of some [redacted] circuits at Taegu [redacted]
Telegraph Repeater, [redacted]	Failure results in loss of hubbing capability for two [redacted] circuits. Restoral for only one end terminal can be accomplished by patching past the failed unit, or for all channels by repair.
Power Supply [redacted]	Failure results in the loss of all [redacted] channels. Restoral is by repair.
Converter, Low to High Level [redacted] Converter, High to Low Level [redacted] Current Regulator, Low Level [redacted]	Failure results in the loss of all [redacted] channels Numerous spares are available for restoring the unit.
Audio Limiter [redacted] Power Supply [redacted]	Failure results in the loss of receive capability for voice circuits on M/W. Some spares are available for repairing the units, or the signal patch can be restored by patching past the failed unit if loss of voice quality is acceptable.

[redacted]

[redacted]

D.2.2 Microwave Terminal (MWT)

Message traffic is transmitted between [redacted] and other facilities via microwave radio or twisted pairs carrying audio or pulse code modulation signals. Figure D.2-2 shows the communications functional flow and associated equipment.

The microwave links to [redacted] and [redacted] are [redacted] systems operating in a dual frequency diversity mode. The [redacted] microwave link to [redacted] operates at a single frequency, with the second transmitter/receiver in hot standby. The microwave link to [redacted] uses a [redacted] system operating in a dual frequency diversity mode. The [redacted] microwave link uses a [redacted] system and also operates in a dual frequency diversity mode. The link capacities and operating frequencies are shown in Table D.2-2.

Table D.2-2. Link capacities and operating frequencies, [redacted]

[redacted]	Transmit (MHz)	Receive (MHz)	Channel Capacity
[redacted]	[redacted]	[redacted]	84
			600
			420
			240
			36

[redacted]

[redacted]

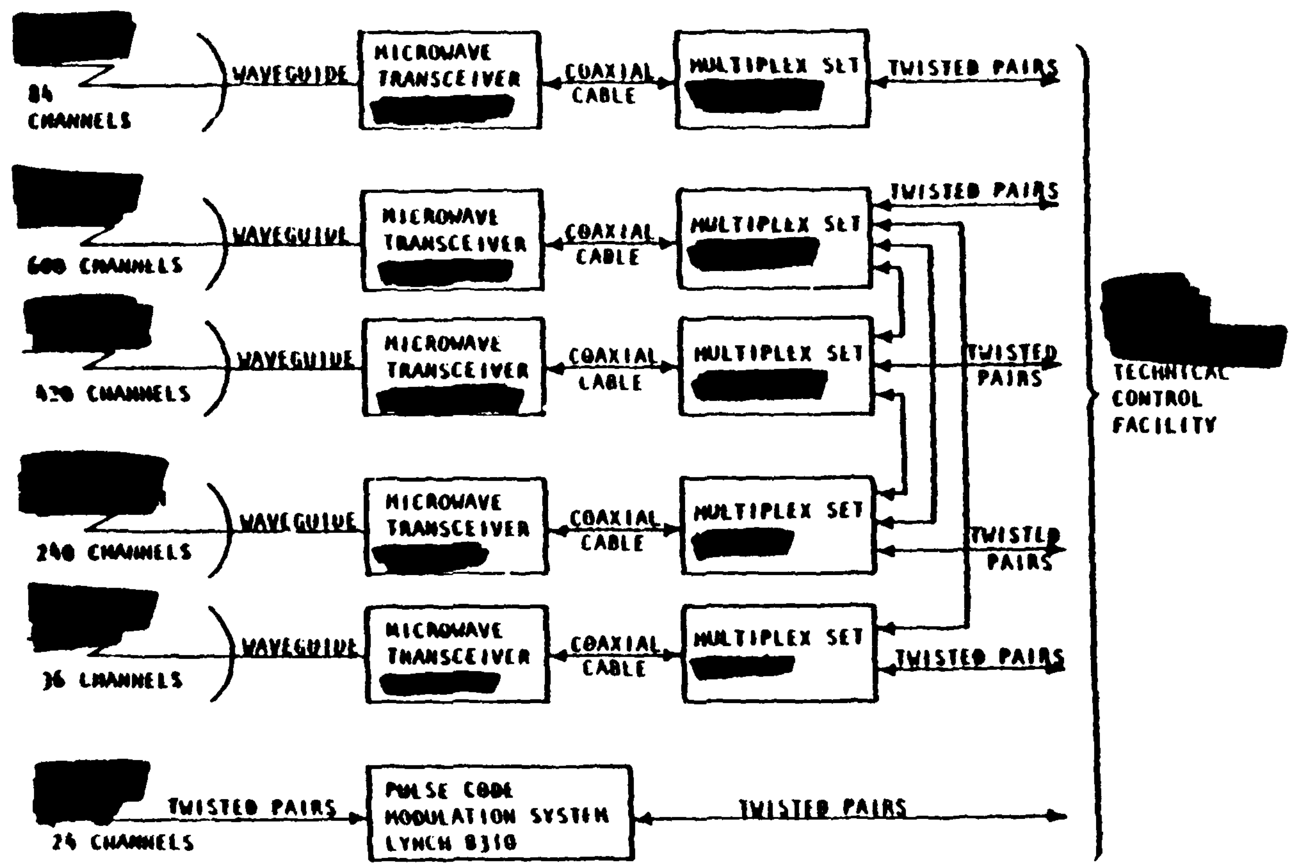


Figure 8.2-2. Communications functional flow and associated equipment, [redacted]

[redacted]

[redacted]

The [redacted] pulse code modulation system (PCM) carries 24 channels as a backup for the [redacted] microwave system. The [redacted] MWT system is not capable of carrying the wide-band secure voice link between [redacted] and [redacted] which requires one group (12 channels) of the [redacted] microwave link.

The link from the MWT to [redacted] is comprised of 120 channels for U.S. Forces and 120 channels for [redacted] The 120 channels for the U.S. Forces split at [redacted] and follow the [redacted] microwave system, with 60 channels terminating at [redacted] and 60 at [redacted] Sixty channels are therefore available for alternate path backup between [redacted] and both [redacted] and [redacted] The 120 channels reserved for [redacted] use provide a similar alternate, with 60 channels following the U.S. Forces microwave system to [redacted] and 60 channels to [redacted].

Results of the functional analysis indicate that the equipment listed in Table D.2-3 are critical for operating the MWT. Included for each critical equipment is the functional impact to microwave terminal operations if the equipment is impaired.

[redacted]

[redacted]

Table 9.2-3. [redacted] MWT functional response matrix for critical equipment.

Critical Equipment	Functional Response
Power Supply, [redacted] 00050	Failure results in the loss of MWT message receive and transmit capability after depleting the minimum 8-hour battery backup reserve.
Microwave Transceiver, [redacted]	
DC Power	Failure results in the loss of receive and transmit capability to [redacted]. Restoring the 60 channels to [redacted] and the 60 channels to [redacted] can be accomplished by using the [redacted] bypass radio to [redacted]. Restoring the [redacted] link and the additional [redacted] and [redacted] channels can be accomplished following repair of the damaged equipment.
Receive Output	Failure results in the loss of receive capability from [redacted]. Restoration as above.
Transmit Input	Failure results in the loss of transmit capability to [redacted]. Restoration as above.
Multiplexer, [redacted] DC Power	Failure results in the loss of receive and transmit capability to/from [redacted]. Restoring the 60 channels to [redacted] and the 60 channels to [redacted] can be accomplished by using the [redacted] bypass radio to [redacted]. Restoring the [redacted] link and additional [redacted] and [redacted] channels can be accomplished following repair of the damaged equipment.
Receive Input	Failure results in the loss of receive capability from [redacted]. Restoration as above.
Transmit Output	Failure results in the loss of transmit capability to [redacted]. Restoration as above.

[redacted]

Table B.2-3. [redacted] functional response matrix for critical equipment (continued).

Critical Equipment	Functional Response
Multiplexer, [redacted] (continued)	
VF Input	Failure results in the loss of transmit VF capability to [redacted] Restoration as above.
VF Output	Failure results in the loss of receive capability from [redacted] Restoration as above.
Microwave Transceiver, [redacted]	
DC Power	Failure results in the loss of message receive and transmit capability to the [redacted] satellite terminal. Restoring all channels, except wideband secure voice, can be accomplished using the backup [redacted] cable carrier system.
Receive Output	Failure results in the loss of message receive capability from the [redacted] satellite terminal. Restoration as above.
Transmit Input	Failure results in the loss of message transmit capability to the [redacted] satellite terminal. Restoration as above.
Multiplexer, [redacted]	Failure results in the loss of message traffic to and from [redacted] Restoration as above.
Pulse Code Modulation System, [redacted]	
DC Power	Failure results in the loss of the backup message transmission system to/from the [redacted] satellite terminal. Restoring the message transmission capability can be accomplished by using normal microwave radio and multiplexer link, or by repair.
PCM Output	Failure results in the loss of the backup transmit capability to [redacted] Restoration as above.

[redacted]

[redacted]

Table D.2-3. [redacted] functional response matrix for critical equipment (continued).

Critical Equipment	Functional Response
Pulse Code Modulation System, [redacted] (continued)	
VF Input	Failure results in the loss of the backup transmit capability to [redacted] Restoration as above.
PGM Input	Failure results in the loss of the backup receive capability from [redacted] Restoration as above.
VF Output	Failure results in the loss of the backup receive capability from [redacted] Restoration as above.
Microwave Transceiver, [redacted]	
DC Power	Failure results in the loss of the alternate route via [redacted] microwave for 60 channels. Restoration by using prime route.
Receive Output	Failure results in the loss of the receive capability from [redacted] Restoration as above.
Transmit Output	Failure results in the loss of transmit capability to [redacted] Restoration as above.
Multiplexer, [redacted]	
DC Power	Failure results in the loss of the alternate route via [redacted] microwave for 60 channels. Restoring the alternate route can be accomplished using prime route.
Transmit Output	Failure results in the loss of transmit capability to [redacted] microwave. Restoration as above.
VF Input	Failure results in the loss of transmit capability to [redacted] microwave. Restoration as above.

[redacted]

Table D.2-3. [redacted] functional response matrix for critical equipment (continued).

Critical Equipment	Functional Response
Multiplexer, [redacted] (continued)	
Receive Input	Failure results in the loss of receive capability from [redacted] microwave. Restoration as above.
VF Output	Failure results in the loss of receive capability from [redacted] microwave. Restoration as above.

[redacted]

APPENDIX E

[redacted] FACILITY ELECTROMAGNETIC ANALYSIS

E.1 GENERAL

The construction of the buildings housing the [redacted] TCF and MWT is concrete block with some steel reinforcement. The building shielding for the TCF was estimated at the site to be [redacted] Direct coupling of EMP to internal conductors is treated in the EM model by attenuating incident EMP fields by [redacted] The building shielding for the MWT was measured during the site survey to be [redacted] Direct coupling of EMP to internal conductors is treated in the EM model by attenuating incident EMP fields by [redacted]

E.2 [redacted] TCF PENETRATIONS AND COUPLING PATHS

Figure E.2-1 shows the major electromagnetic penetrations of the TCF. These major electromagnetic penetrations are listed below:

1) The communication tie cables between the TCF and the microwave building
2) The dc power cables between the TCF and the microwave building
3) The landline communications cables
4) The [redacted] main distribution frame tie cables
5) The ground system
6) The ac power system via the [redacted] facility UPS room

Considering the major electromagnetic penetrations and the TCF critical equipment, the critical coupling paths joining these penetrations and critical equipment were selected for the EM analysis.

[redacted]

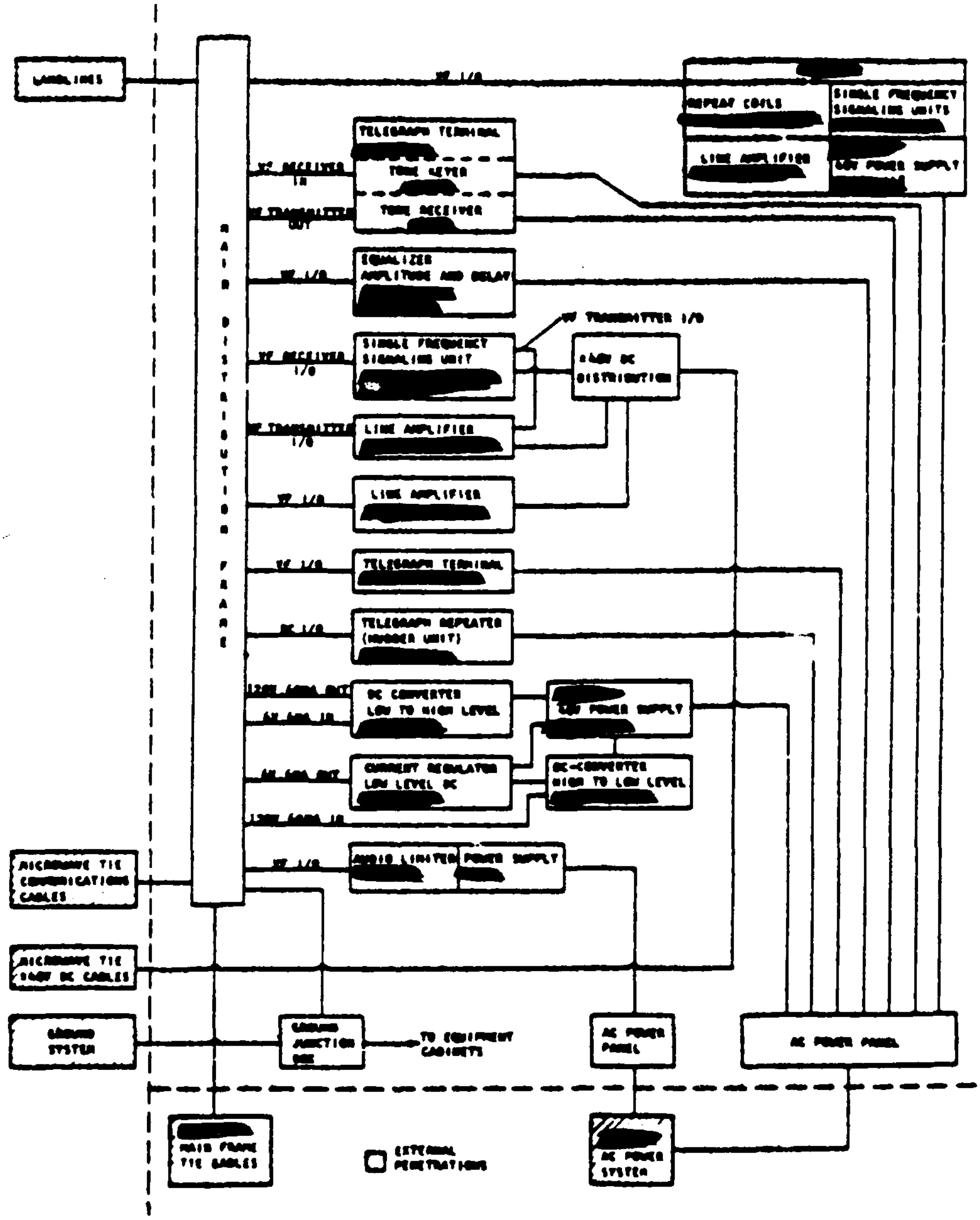


Figure E.2-1. Major penetrations and coupling paths, [redacted]

[redacted]

E.3 [redacted]MWT PENETRATIONS AND COUPLING PATHS

Figure E.3-1 shows the major electromagnetic penetrations of the MWT. These major electromagnetic penetrations are listed below:

1) Commercial power feed lines
2) Microwave tower and waveguide system
3) Buried communication cables
4) Ground system conductors

Considering the major penetrations and the MWT critical equipment, the critical coupling paths joining these penetrations and critical equipment were selected for the EM analysis.

E.4 EM MODEL DEVELOPMENT

The locations and shielding of the penetrations, the layout of the coupling paths and the location and type of critical circuit determine the configuration of the final electromagnetic model coded into a computer to calculate the critical equipment responses to the most severe, high-altitude, nuclear EMP environment.

[redacted]

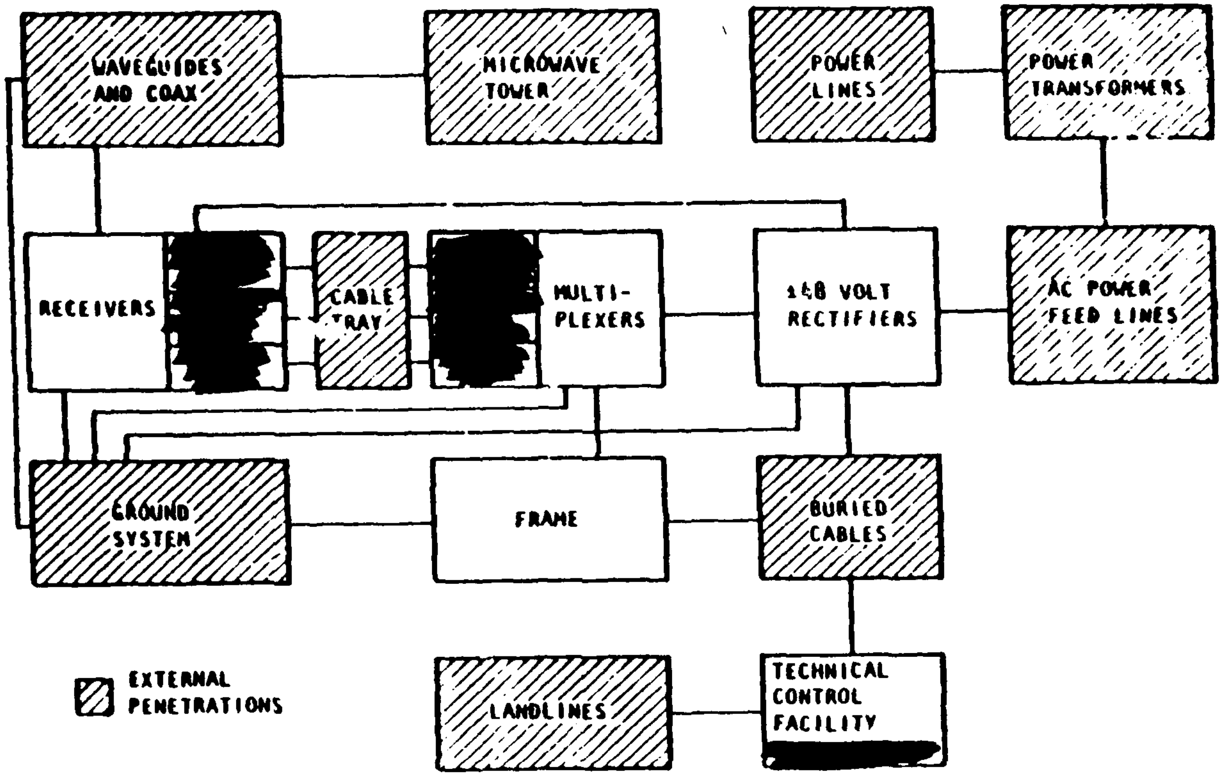


Figure E.3-1. Major penetrations and coupling paths, [redacted] MWT.

[redacted]

APPENDIX F

[redacted] BONDING* AND ASSEMBLY INSTRUCTIONS

F.1 BONDING

Bonding refers to the process by which a low impedance path for the flow of an electric current is established between two metallic objects.

F.1.1 Surface Platings or Treatments

Surface treatments, to include platings provided for added wearability or corrosion protection, shall offer high conductivity. Plating materials shall be electrochemically compatible with the base metals. Unless suitably protected from the atmosphere, silver and other easily tarnished metals shall not be used to plate the bond surfaces.

F.1.2 Bond Protection

All bonds shall be suitably protected against weather, corrosive atmospheres, vibrations and mechanical damage. Under dry conditions a corrosion preventive or sealant shall be applied within 24 hours of assembly of the bond materials. Under highly humid conditions, sealing of the bond shall be accomplished within one hour of joining.

F.1.3 Corrosion Protection

Each bonded joint shall be protected against corrosion by assuring that the metals to be bonded are galvanically compatible in accordance with DCA Notice 310-70-1**. Bonds shall be painted with a moisture proof paint conforming to the requirements of FED-STD T-TP-1757 or shall be sealed with a silicone or petroleum-based sealant to prevent moisture from reaching the bond area. Bonds

* taken from MIL-STD-188-124

**DCA Notice 310-70-1 will be replaced by MIL-HDBK-419 upon release of 419.

[redacted]

[redacted]

which are located in areas not reasonably accessible for maintenance shall be sealed with permanent waterproof compounds.

F.1.4 Vibration

Bonds shall be protected from vibration-induced deterioration by assuring that bolts and screws are torqued in accordance with DCA Notice 310-70-1.

F.1.5 Bonding Straps

Bonding straps installed across shock mounts or other suspension or support devices shall not impede the performance of the mounting device. They shall be capable of withstanding the anticipated motion and vibrational requirements without suffering metal fatigue or other means of failure. Extra care shall be utilized in the attachment of the ends of bonding straps to prevent arcing or other means of electrical noise generation with movement of the strap.

F.1.6 Bond Resistance

All bonds for ground conductors whose primary function is to provide a path for power, control, or signal currents shall have a maximum dc resistance of one milliohm. The resistance across joints or seams in metallic members required to provide electromagnetic shielding shall be one milliohm or less.

F.1.7 Clamps

Bonding clamps shall conform to AN 735 or AN 742.

F.1.8 Nuts, Bolts, and Washers

Nuts and bolts shall be capable of meeting the torque requirements of DCA Notice 310-70-1. Flat washers shall not be surface treated: they shall be protected as specified in paragraph F.1.18 and F.1.19 for corrosion control purposes. Star washers smaller than 1.2 cm (1/2 inch) shall not be used.

[redacted]

[redacted]

F.1.9 Direct Bonds

Wherever possible, bonding of metallic or other conductive members shall be accomplished by direct contact of the mating surface with the electrical path achieved by a welded, brazed, soldered, or high-compression bolted connection.

F.1.10 Welding

Permanent conditions between ferrous materials shall be welded whenever possible.

F.1.11 Brazing and Silver Soldering

Brazing or silver soldering is acceptable for the permanent bonding of copper and copper alloy materials.

F.1.12 Bonding of Copper to Steel

Either brazing or exothermic welding shall be used for the permanent bonding of copper conductors to steel or other ferrous structural members.

F.1.13 Soft Soldering

Soft soldering shall not be used for bonding purposes.

F.1.14 Sweat Soldering

Sweat soldering shall be used for electrical bonding only when other fasteners such as bolts or rivets are concurrently used to provide mechanical strength.

[redacted]

F.1.15 Bolting

All bonds utilizing bolts and other threaded fasteners shall conform to the minimum torque requirements given in DCA Notice 310-70-1. Inspection shall be conducted periodically. Before joining, all faying surfaces shall be prepared per paragraph F.1.18. Particular care shall be taken to provide adequate corrosion protection to all electrical bonds made with bolts and other threaded fasteners.

F.1.16 C-Clamps and Spring Clamps

C-clamps and spring clamps shall not be used for permanent or semi-permanent bonding.

F.1.17 Indirect Bonds

Where the direct joining of structural elements, equipments, and electrical paths is impossible or impractical to achieve, bonding straps or jumpers shall be used.

F.1.18 Surface Preparation

All mating surfaces which comprise the bond shall be thoroughly cleaned before joining to remove dust, grease, oil, moisture, nonconductive protective finishes, and corrosion products.

1) Area to be Cleaned. All bonding surfaces shall be cleaned over an area that extends at least .5 cm (1/4 in.) beyond all sides of the bonded area on the larger member.
2) Paint Removal. Paints, primers, and other organic finishes shall be removed from the metal.
3) Inorganic Film Removal. Rust, oxides, and nonconductive surface finishes such as anodize shall be removed.

4) Final Cleaning. After initial cleaning with chemical paint removers or mechanical abrasives, the bare metal shall be wiped or brushed with dry cleaning solvent meeting the requirements of Federal Specifications P-D-680. Surfaces not requiring the use of mechanical abrasives or chemical paint removers shall be cleaned with a dry cleaning solvent to remove grease, oil, corrosion preventives, dust, dirt, and moisture prior to bonding.

5) Clad Metals. Clad metals shall be cleaned with fine steel wool or grit in such a manner that the cladding material is not penetrated by the cleaning process. A bright, smooth surface shall be achieved. The cleaned area shall be wiped with dry cleaning solvent and allowed to air dry before completing the bond.

6) Aluminum Alloy. After cleaning of aluminum surfaces to a bright finish, a brush coating of iridite or other similar conductive finishes shall be applied to the mating surfaces.

7) Completion of the Bond. If an intentional protective coating is removed from the metal surface, the mating surfaces shall be joined within 30 minutes after cleaning.

F.1.19 Dissimilar Metals

All mating surface materials that comprise a bond shall be identified. Compression bonding with the use of bolts or clamps shall be utilized only between metals having acceptable coupling values as indicated in DCA Notice 310-70-1. When the base metals form couples that are not allowed, the metals shall be plated, coated, or otherwise protected with a conductive finish, or a material compatible with each shall be inserted between the two base metals. It shall be constructed from or plated with an appropriate intermediate metal.

F.1.20 Corrosion Prevention (Below Grade)

Because of galvanic corrosion between dissimilar metals, below grade and/or high moisture areas, the welded or brazed joint shall be covered with pitch or other suitable waterproof compound to inhibit corrosion.

F.2 ASSEMBLY

The following subparagraphs deal with special installations peculiar to hardness concept designs.

F.2.1 Rigid Conduit, Threaded Connections

Rigid conduit (new or old installations) used for shielding or rf returns shall be assembled as follows:

1) Cleaning. All mating surfaces for threaded connections shall be prepared as in paragraph F.1.18.
2) Assembly. Apply cold galvanizing compound* "Galvicon" to thread parts and assemble wet. Wipe off excess and let joint dry.
3) Corrosion Protection. Protect the connection as in paragraph F.1.3.

F.2.2 Rigid Conduit, Box or Cabinet Connection

Rigid conduit (new or old installations) used for shielding or rf returns shall be assembled as follows:

1) Cleaning. All faying surfaces shall be prepared as in paragraph F.1.18.

* Kenco Divison
Southern Coatings and Chemical Co., Inc.
Sumter, South Carolina 29150

[redacted]

2) Assembly. Assemble using a rigid conduit metallic bushing and bonding type lock nut.

3) Corrosion Protection. Protect the connection as in paragraph F.1.3.

F.2.3 Coaxial Cable, Severe Environment

Coaxial cable connections exposed to outdoor environments or high humidity shall be assembled as follows:

1) Cleaning. All metal surfaces shall be prepared as in paragraph F.1.18.

2) Assembly. Assemble connectors and clean as in paragraph F.1.18.

3) Corrosion Protection. Apply Dow Corning** 3145 RTV adhesive/sealant (non-corrosive) on the connector forming a seal to preclude migration of water or vapor down the cable or at the threaded portion of the connector.

F.2.4 Coaxial and Shielded Cable, Intermediate Point Bonding

Cables requiring attachment of ground straps at points other than cable ends shall be prepared as follows:

1) Cleaning. Remove at least 3 cable diameters of the protective sheath to expose the cable shield. Prepare the shield surfaces as in paragraph F.1.18 except that any solvents used for cleaning shall be compatible with the cable dielectric and the insulating material.

** Dow Corning Corporation
Midland, Michigan 48640

[redacted]

[redacted]

2) Assembly. Shield bonding is achieved by using a cable clamp to which a flat bonding strap is attached. To avoid crushing the cable dielectric and insulating material, fabricate a pressure sleeve which will be installed under the bonding clamp to distribute clamping pressure over a larger area. The pressure sleeve should be flared on each end, split to facilitate assembly and have a length of about 2 cable diameters. Thin wall copper tubing slightly smaller than the cable diameter should be used and tinned both inside and out with a 50/50 solder using a non-corrosive flux. Install the sleeve and an AN735 type bonding clamp. Prepare a bonding strap of tinned copper flat braid of the largest size possible that is compatible with the terminal lug size determined by the required pressure clamp size. The bonding strap should not be more than 6 inches long and shorter if possible. Crimp and solder a lug to each end of the flat braid. Clean the metal parts as in paragraph 1) above and assemble the sleeve, clamp and bonding strap terminal to the cable. Tighten the clamp, but not so tight as to crush the dielectric or wire insulation. Fasten the other end of the bond strap to the ground plane in accordance to the bonding instructions in paragraph F.1.

3) Corrosion Protection. Apply Dow Corning** 3145 RTV adhesive/sealant (non-corrosive) to the cable, sleeve and bonding clamp. Completely cover the bond assembly, overlapping the protective sheath on the cable and the terminal lug on the clamp. Thus, forming a seal to preclude migration of water or vapor down the cable.

** Dow Corning Corporation
Midland, Michigan 48640

[redacted]